UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

PRELIMINARY REPORT RELATIVE TO BIOLOGICAL FACTORS IN THE CONTROL OF THE MOUNTAIN PINE BEETLE

1937 Investigations

By
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Coeur d'Alene, Idaho
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Forest Insect Laboratory
Coeur d'Alene, Idaho
April 12, 1938

Dr. F. C. Craighead
Washington
D. C.

Dear Dr. Craighead:

There is enclosed the second report from our infestation study in white pine, by Mr. W. D. Bedard, entitled "Preliminary Report Relative to Biological Factors in the Control of the Mountain Pine Beetle - 1937 Investigations". I am sure you will find this report to be of interest, and we should like very much to have your frank comments and suggestions. We have again been assured that we can have a small crew of CCC laborers this season for the continuation of this project, which will make your suggestions especially valuable to us.

We are interested in this study as it relates to our attempt to direct artificial contfol in such a manner as to preserve the primary beneficial agents. We still believe in the entomological necessity for this action and are hopeful that this study will produce criteria by which those trees harboring sufficient numbers of beneficial agents can be left untreated. Data which we have secured indicate that these so-called beneficials play an important part in determining the fluctuations of mountain pine beetle infestations in white pine. As yet we are unable to give a relative weight to the different insects and factors concerned, but with more information permitting a proper evaluation, we hope to be able to predict with a fair degree of accuracy normal fluctuations in mountain pine beetle infestations.

An extra copy of this report is enclosed for circulation through the eastern laboratories if you so desire.

Again trusting that we may have your comments and suggestions, I remain

Respectfully yours,

James C. Evenden
Senior Entomologist

Enclosures

cc to:
Mr. Miller, Mr. Keen, Mr. Beal

CONTENTS

BIOLOGICAL FACTORS IN THE CONTROL OF
THE MOUNTAIN PINE BEETLE

Although the subject of biological control has been thoroughly discussed by a number of authors, there still continues to be considerable controversy in any discussion of the subject. The beneficial effect of biological agencies appears to be dubious under certain circumstances, while under other conditions it appears to be decidedly advantageous. It is the object of this study therefore to evaluate the various natural agencies effective in the control of the mountain pine beetle and to attempt some modification of control practices whereby the benefits of natural control would not be nullified by mechanical methods.

To this end data have been gathered during the past two seasons from an infestation of the mountain pine beetle in western white pine on the Coeur d'Alene National Forest. The study was actually begun several years ago, but it was only during the past two seasons that a crew of eight CCC enrollees and an experienced foreman were available to secure volumetric data in conjunction with a detailed study of the mountain pine beetle infestation.

During the first part of the project each tree was felled and examined at 10-foot intervals along the bole, starting at 5 feet. Later, however, the interval was extended to 20 feet when it was found that this could be done without altering the character of the data, so that examinations were made therefore at 5, 20, 40, 60 feet, etc., up to the height of infestation. The 5-foot sample was considered representative of the basal 10 feet of the bole, the 20-foot sample represented

the next 20 feet, the 40-foot sample from 30 to 50 feet, etc. The last sample was taken at a point midway between the top of the last 20-foot log and the height of infestation. At each point of examination one-half square foot of bark was removed on the north, east, south, and west sides of the tree and complete insect population data were recorded for each half square foot sample.

In totalling these data sheets, the total population for each log was first determined. Then the totals for each individual factor in each log were added together and their sum divided by the total bark surface of the tree in order to secure the tree average for each factor. In this way the unequal bark surface represented by the various samples was weighted and the total for the tree was more accurate. In addition to insect population data such information as tree class, diameter and bark thickness at each sample, crown shape, rate of growth, presence or absence of wood and root rots, site, exposure, and total height were recorded for each tree.

IMPORTANCE OF BIOLOGICAL AGENTS IN CONTROL

In relation to infestations of the mountain pine beetle in western white pine, there is no doubt that for the most part the action of biological agents is beneficial. In the development of the mountain pine beetle from egg to emergence there is an average mortality of approximately 90 percent which is caused to a large extent by various biological agencies. Table I has been prepared to show the progressive mortality which occurs throughout the various developmental stages.

Table I

MORTALITY TO MOUNTAIN PINE BEETLE DURING DEVELOPMENT

Developmental stage	Trees examined	Bark surface	Av. per sq. ft.	Decrease to succeeding stage		Percent total decrease
	No.	Sq.ft.	No.	No.	Percent	
Egg	36	8,044	176.1	74.2	42.2	42.2
Small larva	41	7,127	101.9	39.1	38.4	22.2
Large larva	37	6,273	62.8	24.4	38.8	13.8
Pupa	24	4,287	38.4	6.6	17.3	3.8
New adult	20	4,262	31.8	7.6	24.0	4.3
Emergence	16	2,830	24.2			
Total	174	32,823	176.1	151.9		86.3

It is quite apparent in table I that mortality factors are decidedly important in holding down infestations of the mountain pine beetle. Chief among the various causes of mortality are the biological agents such as mites, which are active in destroying eggs; parasites, which are effective in reducing the number of larvae; and predators, which attack larvae, pupae, and adults.

In table II mountain pine beetle population is shown according to the number of parasites and predators per square foot.

Table II

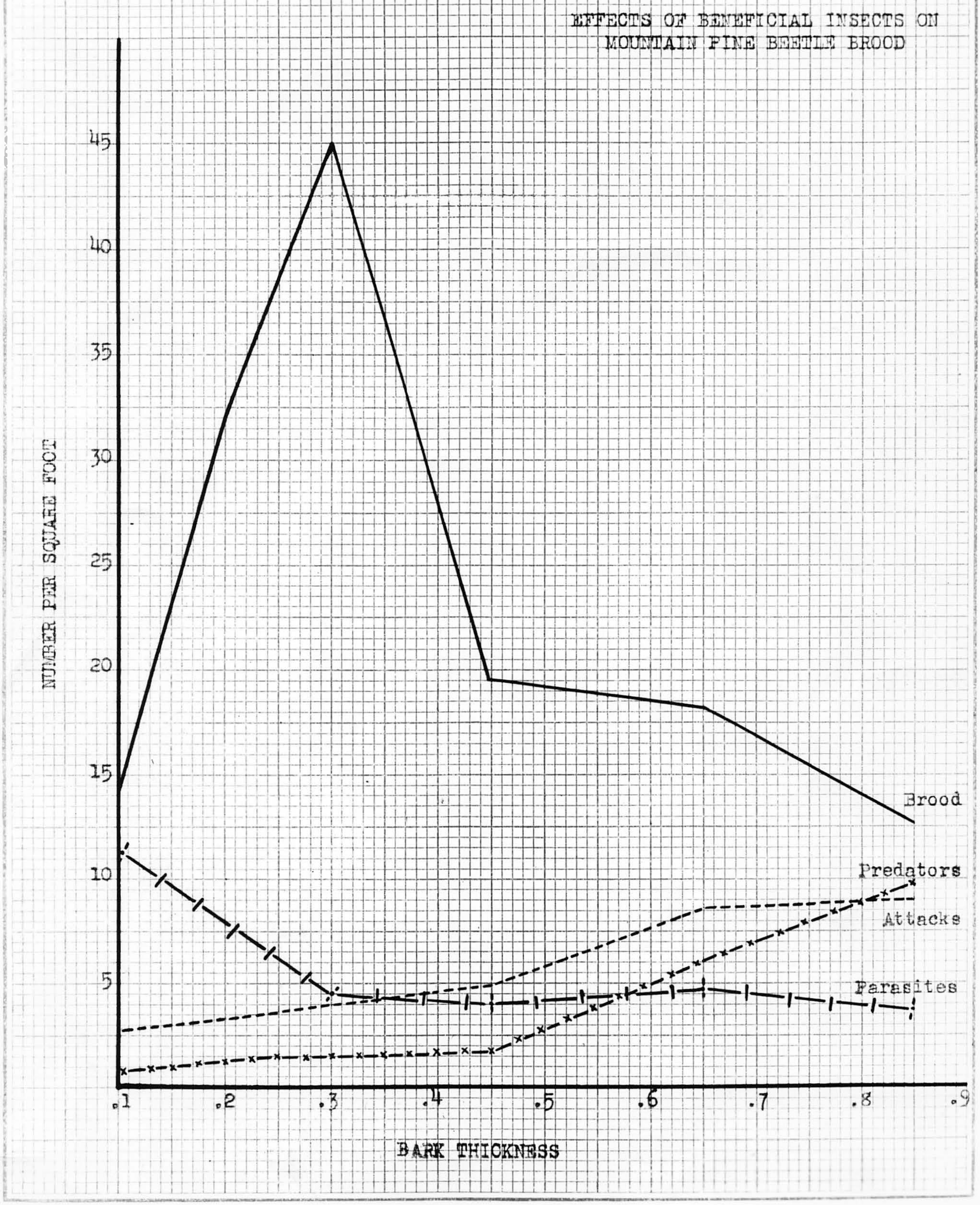
BROOD ACCORDING TO PARASITIZATION

Parasites and predators per square foot	Trees examined	Bark surface	Average per square foot	
			D.m. brood	Attacks
No.	No.	Sq.ft.	No.	No.
1-10	93	18,095	38.9	3.3
11-20	9	1,442	39.6	3.4
21+	4	721	20.6	3.3

Table II shows that in spite of equal density of attack there is a decided reduction in mountain pine beetle broods in those trees averaging better than 21 beneficials per square foot. There is, however, no appreciable difference between the first two groupings. This probably results from the fact that parasites and predators have been grouped together and although both are effective, they have different efficiency values and therefore should not be considered together. This point is more clearly shown in plate I, in which the abundance of mountain pine beetle broods and attacks is compared with the number of parasites and predators. As will be shown later, accessibility of host material is the main factor governing the abundance of beneficials, and as bark thickness is most important in determining accessibility, it has been used as one axis for plotting the curve while abundance has been used as the other.

In these curves it is apparent that, in spite of more attacks in thicker bark, maximum mountain pine beetle broods are found under bark .3 inch thick. It is logical to assume that beneficial insects account for a large portion of this decrease because parasites are most abundant in the thin bark while predators attain their maximum in the thick bark. The parasite curve does not drop rapidly in the thick bark owing to the fact that the two small chalcids Pachyceras and Cecidostiba, which go beneath the bark to oviposit, are found where mountain pine beetle parent-emergence holes are most numerous, which is usually in the thicker bark. From the foregoing discussion it is apparent that biological agencies do play an important role in reducing

PLATE I


EFFECTS OF BENEFICIAL INSECTS ON
MOUNTAIN PINE BEETLE BROOD
NUMBER PER SQUARE FOOT
45
40
35
30
25
20
15
10
5
.1
.2
.3
.4
.5
.6
.7
.8
.9
BARK THICKNESS
Brood
Predators
Attacks
Parasites

broods of the mountain pine beetle.

GENERAL COMPARISON OF ABUNDANCE

Two seasons' data are available to compare the status of beneficial biological factors. In table III the beneficial agencies have been divided to show woodpecker work, insect parasites, insect predators, work by secondary bark beetles and wood-boring beetles. The last two have been grouped under the heading "robber work". These data are compared with mountain pine beetle broods for the 1935 and 1936 seasons. The year of attack has been used to designate the infestation, although examination of these trees was made in the year of emergence, which would be one year after attack.

Table III

ABUNDANCE OF BENEFICIAL BIOLOGICAL AGENTS DURING 1935 AND 1936

Year	Trees examined	Bark surface	Average per square foot				
			Brood	Parasites	Predators	Robber work	Woodpecker work
1935	133	25,327	7.7	4.7	2.4	7.7	6.6
1936	106	20,258	38.3	3.6	1.4	18.0	5.2

Table III shows that mountain pine beetle brood was very scarce in the 1935 trees owing to mortality. The cause of this mortality is not known. It was in the fall of 1935 that a sudden drop in temperature occurred which killed considerable pine foliage, but as the bark-beetle mortality occurred in first- and second-instar larvae, the period of death would be placed prior to the time of the freeze. It will also be

noted in table III that in 1936 there was an increase in robber work, with decreases in parasites, predators, and woodpecker work. The increased brood in 1936 probably represents close to normal abundance and might account for the decrease in woodpecker work because the woodpeckers would obtain five times as much food from one square foot of bark as in the previous year. Work by secondaries and woodborers is twice as great in 1936 as in 1935, probably due to the fact that attacks by the mountain pine beetle are less numerous, thus allowing these insects to concentrate in the lower bole rather than in the top above the height of mountain pine beetle infestation.

The noticeable decrease in parasites and predators is difficult to explain. If it occurred prior to the emergence of parasites and predators it might have been caused by starvation or cannibalism owing to the scarcity of brood in the 1935 trees. If it occurred after emergence, however, it might have resulted from a lack of suitable places for oviposition owing to the decrease in number of trees infested in 1936. Some beneficials showed greater losses than others as shown in table IV.

Table IV

CHANGE IN STATUS OF BENEFICIALS BY SPECIES

Insect	Average per square foot 1935	Average per square foot 1936
Coeloides	4.6	3.1
Chalcids	.2	.5
Medetera	.9	.8
Lonchaea	1.1	.1
Clerids	.3	.4
Ostomids	.1	.1
Phaonia	.01	.003

In table IV it is shown that the two chalcids *Cecidostiba* and *Pachyceras* increased over the previous year so that of the parasites *Coeloides* alone showed a decrease. Among the predators, *Medetera* decreased but slightly, clerids increased, and ostomids remained unchanged, so that *Phaonia* and *Lonchaea* suffered most of the loss apparent among the predators. Since *Phaonia* is of such low abundance as to be of little influence, practically all of the loss resulted from a decrease in *Lonchaea*. It is interesting to note in this case that decreases occurred only in those insects which pupate within a definite pupal case.

EFFECT OF VARIOUS FACTORS ON ABUNDANCE

There are certain limiting factors which affect the population of beneficial agencies. These factors are discussed in the following section under the headings: Availability of host, site moisture, accessibility of host, tree diameter, exposure, and location.

Availability of Host

As would be expected, it is essential that host material suitable for oviposition must be available at the time when adult parasites and predators are emerging. Table V shows the abundance of beneficial agents in trees attacked at various times during the season. Early attacked trees are those attacked by the mountain pine beetle during June, midseason attacks occur during July and the fore part of August, while late attacks are made from late August to the end of the season.

Table V

POPULATION OF BENEFICIALS IN VARIOUS ATTACK PERIODS

Year	Attack period	Average per square foot: Parasites	Predators	Secondary work	Cerambycid work	Woodpecker work
		No.	No.	Sq.in.	Sq.in.	Sq.in.
1935	Early	7	3.8	4.9	5.8	8.7
	Midseason	3.7	1.8	4.5	2.2	6.1
	Late	3.7	1.2	6.6	.3	.1
1936	Early	3.3	1	10.2	5.2	8.1
	Midseason	4.7	1.5	9.7	2.6	4.7
	Late	1.6	1.7	32.8	1.9	1.3

According to the data shown in table V parasites were most plentiful in the early attacks of 1935 and equal in abundance in the midseason and late attacks of that year. In 1936, however, the greatest number occurred in the midseason attacks, less in the early attacks and least in the late attacks. The 1935 data represent the normal condition in which most parasitization occurs in the early attacked trees. The reason for this is that during August when most of the parasites oviposit the early attacks contain mostly mature larvae, thus providing the greatest quantity of suitable host material for the parasites. At this time, only a few of the earlier midseason attacks have attained sufficient development to provide suitable hosts, while a few of the previous season's late attacks also contain suitable larvae. Most of the predators are also found in the early attacks because these are the only attacks which have been perpetrated when most of the predators oviposit early in the season.

During 1936 some variation from the normal is to be noted in parasites and predators. The cause of this variation is difficult to

explain except on the basis of a heavier mortality among these beneficials due to a loss of synchronization with their host. It is known that the 1935, 1936, and 1937 seasons witnessed some changes in mountain pine beetle seasonal history.

Work by secondary bark beetles is most prevalent in late attacks because maximum secondary population is attained at the end of the season. Wood-boring beetles appear during July, when the early attacks are the most suitable trees for oviposition; hence the preponderance of this work in the early attacks. Woodpeckers feed on mountain-pine-beetle-infested trees during the winter months and select the early and midseason attacks because of the more mature broods. Thus it is seen that availability of suitable host limits the action of beneficial agencies.

Site Moisture

A second factor which may properly be considered a corollary of "availability of host" is "abundance of host". In general, parasites and predators seek out trees containing an abundant supply of host material, although there are many heavily brooded trees which do not contain a great number of beneficial insects. This may be only an apparent preference resulting from the fact that a more numerous host may permit a greater amount of oviposition. In table VI parasites and predators are compared with the abundance of mountain pine beetle brood.

Table VI

PARASITES AND PREDATORS ACCORDING TO HOST ABUNDANCE

	D. m. brood per square ft.											
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56+
Parasites per sq.ft	2.2	2.7	5.4	2.7	1.3	10	1.6	3.4	0.8	4.5	3.8	3.3
Predators per sq.ft	1.2	.5	.5	1.4	1.8	1.2	.3	.9	1.6	.6	1	2.7
Average parasites				2.8					4.4			
Average predators				1					1.7			

Table VI shows that there is considerable irregularity when the parasites and predators are compared with mountain pine beetle brood. When, however, the trees are grouped and averaged, it is seen that there are more parasites and predators in those trees containing the greatest amount of mountain pine beetle brood.

The difference is not sufficient, however, to affect the correlation which is shown in table VII, in which the various beneficial agencies are shown according to the moisture of thé site on which the infested tree is growing.

Table VII

STATUS OF BENEFICIAL AGENTS ACCORDING TO SITE MOISTURE

Site moisture	Trees examined	Bark surface	Average per square foot: Brood					
			Brood	Parasites	Predators	Secondary work	Wood-borer work	Wood-pecker work
Wet	19	3,938	61.8	5.4	2	5.3	4.3	8.4
Medium	24	4,783	44.8	4.5	1.7	7	1.3	7.7
Dry	63	11,537	27.5	2.5	1	9.2	3.3	.4

It is apparent in table VII that parasites, predators, and woodpecker work are most plentiful on wet sites and least abundant on dry sites. The opposite is true of secondary bark beetles, while woodborers show no apparent preference.

Accessibility of Host

One of the most important factors governing the effectiveness of parasites and predators in mountain-pine-beetle-infested material is the ease with which the host material may be reached. The parasite *Coeloides dendroctoni* Cush., which oviposits through the bark, is not able to parasitize larvae which are beneath bark thicker than the length of the ovipositor. On the other hand, the two chalcid parasites *Pachyceras eccoptogasteri* Ratz. and *Cecidostiba dendroctoni* Ash. enter the bark by means of parent-adult emergence holes and thus are found most plentiful where these holes are most numerous. In table VIII the distribution of various factors is shown according to bark thickness.

Table VIII

EFFECT OF BARK THICKNESS ON BENEFICIALS

Average 1935 & 1936

	Bark thickness					
	.1	.2	.3	.4-.5	.6-.7	.8-.9
No. samples	35	159	127	222	67	27
Bark surface	1,465	8,217	6,752	9,483	3,040	1,070
Coeloides	11.4	7.5	3.9	3.5	4.5	2.4
Chalcids	.1	.4	.6	.5	.4	1.5
Total parasites	11.5	7.9	4.5	4.0	4.9	3.9
Medetera	.2	.6	1	.6	2.2	3.7
Lonchaea	.02	.2	.1	.4	3.1	4.8
Clerids	.4	.4	.3	.6	.6	1.1
Ostomids	0	.1	.1	.2	.3	.2
Phaonia	.01	0	0	.01	0	0
Total predators	.6	1.4	1.5	1.8	6.1	9.8
D.m. attacks	2.9	3.3	4.1	4.9	8.7	8.9
Parent emergence holes	1.3	2.0	2.3	4.2	8.1	8.9

In this table it can be seen that Coeloides population is greatest in the thinner bark, while the two chalcid parasites are most plentiful in thicker bark where parent-adult emergence holes are more numerous. Similar to the chalcids, all predators tend to be most numerous in the thicker bark for the same reason. These facts are shown more clearly by the curves in plate II.

In table IX the beneficial agencies in the basal ten feet of the tree are compared with their abundance throughout the total infested length.

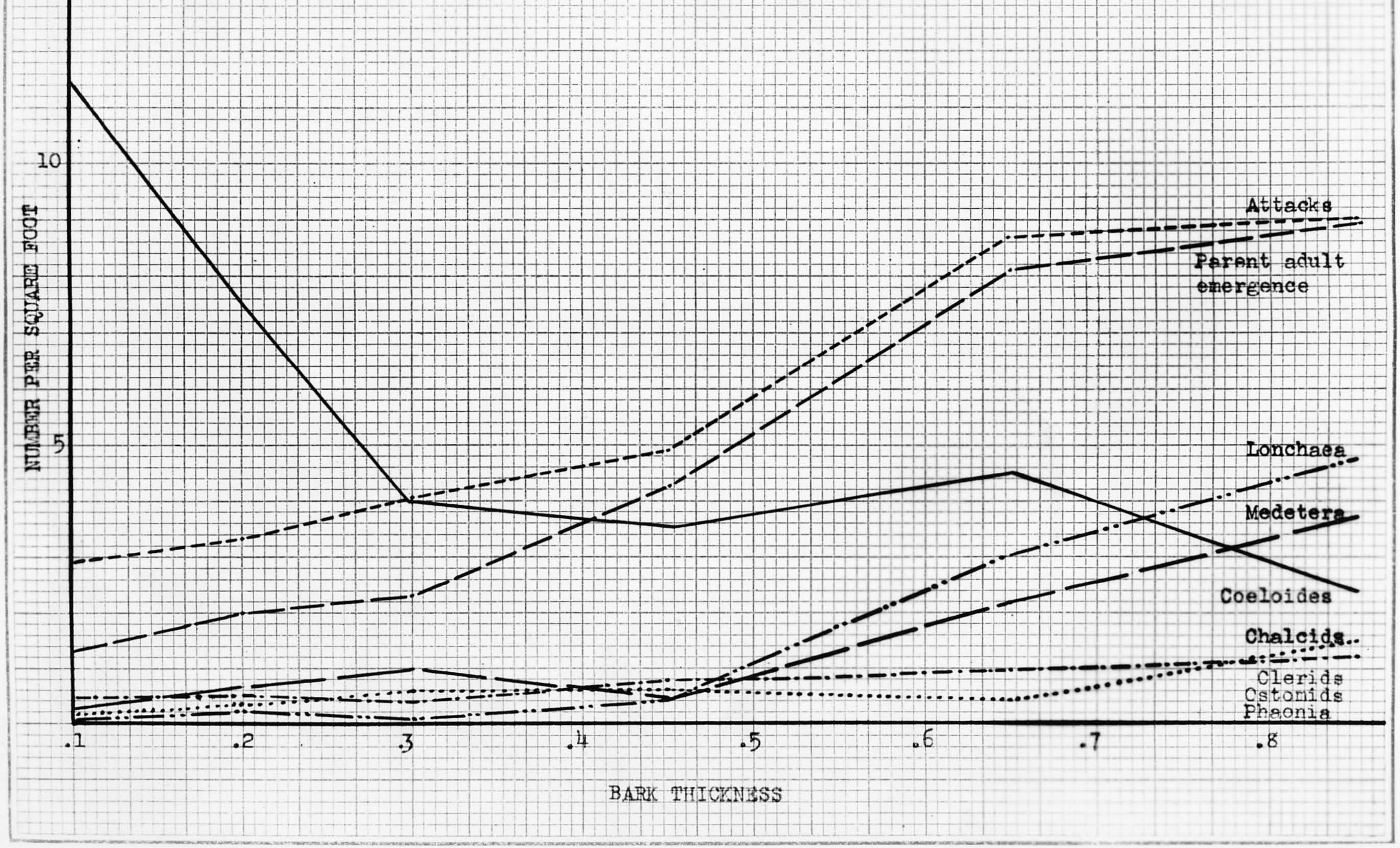
Table IX

ABUNDANCE OF BENEFICIALS AT BASE AND THROUGHOUT TOTAL INFESTED LENGTH

	Average per square foot					
	Parent emergence	Parasites	Predators	Secondary work	Cerambycid work	Woodpecker work
Basal 10 feet	2.6	2.2	1.5	10.8	2.5	6.6
Total length	1.9	3.6	1.4	14.6	3.4	5.2

PLATE II

POPULATION OF BENEFICIALS ACCORDING TO
BARK THICKNESS AND AVAILABLE ENTRANCES



As would be expected, parasites are more numerous in the upper, thinner-barked portion of the tree, while the opposite is true of the predators. Secondaries, which show a preference for drier conditions, are more common in the drier upper portion of the stem.

Tree Diameter

The effect of tree diameter on beneficial insects undoubtedly depends to a large extent upon the influence of accessibility and availability of the host. In table X the various beneficial agencies are shown according to the diameter of the tree.

Table X

EFFECT OF TREE DIAMETER ON BENEFICIALS

Tree diameter	Average per square foot							
	Parasites		Predators		Robber work		D.m. brood	
	1935	1936	1935	1936	1935	1936	1935	1936
Inches								
6-10	5.4	3.5	0.7	0.2	21.2	9.3	3.0	6.2
11-12	11.9	5.8	1.1	0.9	11.2	13.9	6.1	27.1
13-18	4.5	4.7	1.5	1.4	11.6	24.8	7.8	36.8
19-24	4.2	2.3	2.7	1.6	17.3	27.0	8.3	41.7
25+	2.0	0.1	5.6	0.9	15.8	18.5	8.5	36.5

It is apparent in table X that the trees under 10 inches in diameter are nonproductive of mountain pine beetle brood and that they contain a sufficient number of parasites and predators to make the treatment of these trees more harmful than beneficial. Maximum parasite population is found in 11- and 12-inch diameter class because these are the thinnest barked trees which contain sufficient *D.m.* brood.

Exposure

In this section exposure of the site on which the tree is growing

has been eliminated as insignificant because site moisture and site are of such importance as to mask any influence which exposure itself might have. Hence, the discussion has been restricted to the four exposures of the tree bole, the data for which are shown in table XI.

Table XI

BENEFICIALS ACCORDING TO FOUR EXPOSURES OF THE TREE BOLE

	Average per square foot									
	Parasites		Predators		Secondary work		Woodborer work		Woodpecker work	
Exposure	1935	1936	1935	1936	1935	1936	1935	1936	1935	1936
North	4.8	3.6	1.9	1.5	4.7	11.4	2.7	2.6	5.6	4.8
East	5.2	4.2	2.1	1.5	5.5	14.1	3.2	3.1	7.2	5.5
South	4.8	3.0	2.7	1.3	4.8	14.8	4.2	4.0	6.3	4.6
West	4.1	3.5	2.3	1.2	4.1	17.9	3.0	3.8	4.5	6.0

Table XI shows that there is not sufficient variation in these beneficial agents on the four sides of the tree to indicate any influence on abundance. The slight differences apparent in table XI undoubtedly result from the influence of availability and accessibility of host material.

Location

Throughout the course of the infestation study the data have been kept separate for all of the various units on the Coeur d'Alene National Forest. The first year trees were examined on seven units, but during the second the work was concentrated on three units in order to secure a better sample and thus have a better basis for comparing the various areas. In table XII the abundance of beneficial agents is shown for the Honeysuckle, Yellow Dog River, and North

Yellow Dog units for the 1935 and 1936 trees.

Table XII

ABUNDANCE OF BENEFICIALS IN THE VARIOUS UNITS

Unit	1935					1936				
	Trees	Bark surface	Parasites	Predators	Robber work	Trees	Bark surface	Parasites	Predators	Robber work
	No.	Sq.ft.	No.	No.	Sq.in.	No.	Sq.ft	No.	No.	Sq.in.
Honeysuckle	55	13,004	2.6	2.7	13.6	31	8,000	1.5	1.1	28.5
Yellow Dog River	12	2,340	4.6	2.4	14.5	25	3,081	9.9	0.9	21.5
North Yellow Dog	13	2,569	6.5	1.6	18.8	32	5,913	3.8	1.2	18.1

It is apparent in table XII that there is a decided difference in population of beneficials in the different areas and that there has been a considerable change within the units themselves. In the Honeysuckle unit the changes compare with the general average, with a decrease in parasites and predators and an increase in the amount of robber work. In Yellow Dog River, however, there has been an increase in the number of parasites, while in North Yellow Dog the volume of robber work has remained approximately the same. Concerning the units themselves it is readily apparent that there is a decided difference in abundance of the various factors.

It is difficult to explain some of these changes, for example, the increase in parasites in the Yellow Dog River unit when all others show decreases in both parasites and predators. The increase in robber work in Honeysuckle and Yellow Dog River might be explained by the fact

that road construction and logging have provided considerable amounts of slash during the past two years, which may have permitted secondary bark beetles and wood borers to increase. No work of this nature has been done in the North Yellow Dog unit.

From the preceding discussion concerning the effect of various factors on the abundance of beneficial agencies, it is apparent that there is a considerable variation within different infested areas. Within an individual area two factors, namely, accessibility and availability of the host, are most important in determining the abundance of the beneficials. These two major factors are in turn influenced by site and tree diameter. Thus, of the areas examined, parasites for example are most abundant in the Yellow Dog River unit. Within this unit these are concentrated in the thin-barked portions of the smaller early attacked trees which are growing on wet sites. Predators on the other hand are most abundant in the North Yellow Dog unit, in the thick-barked portions of the larger early attacked trees which are growing on wet sites.

Mortality of Beneficials

Very little work has been done to determine the mortality which occurs to beneficials throughout their development. During the spring of 1937, however, ten trees which had been examined in the fall of 1936 were reexamined to determine the changes which had occurred in the abundance of various factors during that period. The results of these examinations are shown in table XIII.

Table XIII

CHANGES IN STATUS OF BENEFICIALS DURING WINTER

Time of examination	Average per square foot				
	Parasites	Predators	Secondary work	Wood borer work	Woodpecker work
	No.	No.	Sq.in.	Sq.in.	Sq.in.
Fall 1936	2.0	1.8	3.4	1.3	0
Spring 1937	1.8	.9	2.7	14.7	.1
% increase or decrease	-10	-50	-22	+1,049	+10

Table XIII shows that there were decreases in parasites, predators, and amount of secondary work, with increases in wood-borer and woodpecker work. These decreases are not dependable, however, because some emergence of parasites and predators had taken place prior to the spring examination and considerable secondary work had been obliterated by the increased amount of wood-borer work. In addition, two of the ten trees were newly attacked at the time of the 1936 examination, so that during the following year there were increases in parasites and predators in these two trees. In table XIV the two newly attacked trees have been separated from the others.

Table XIV

CHANGES IN EARLY AND LATE ATTACKS DURING WINTER

Age of attack	Time of examination	Average per square foot				
		Parasites	Predators	Secondary work	Wood borer work	Woodpecker work
		No.	No.	Sq.in.	Sq.in.	Sq.in.
New	Fall 1936	0	.1	6.2	.9	0
	Spring 1937	1	2.5	8.3	1.9	0
	% change	+100	+3,075	+34	+103	0
Old	Fall 1936	2.5	2.2	2.7	1.4	0
	Spring 1937	2.1	.5	1.1	18.3	.1
	% change	-16	-78	-59	+1,235	+10

Table XIV places a somewhat different interpretation upon these data. In the newly attacked trees which were examined shortly after attack in the fall of 1936, all agencies except woodpecker work showed decided increases. In the remaining trees, which were first examined after considerable development had taken place, all agencies decreased except wood-borer and woodpecker work. Woodpecker work is very scarce in all 10 of these trees, probably due to the fact that they had been felled and were covered with snow during the winter when most of the woodpecker work is done. As previously mentioned, the great increase in wood-borer work probably obliterated some work by secondaries.

PRACTICAL APPLICATION OF THE STUDY

Although only two seasons have been devoted to a detailed study of the beneficial agents associated with mountain pine beetle infestations in western white pine, it is already apparent that addititional study will yield valuable information of a practical nature. For example, in the 1933 control work on the Coeur d'Alene National Forest one area was selected in which all so-called "parasite trees" were left untreated in an attempt to foster an increase of parasites and predators while at the same time the beetle population was decreased. This work entailed the examination of every infested tree in order to ascertain the abundance of beneficial insects, and in many cases there was considerable doubt as to the tree's status. With present knowledge, however, the work would be simplified by restricting it to trees containing an advanced brood stage growing on moist, creek bottom sites.

In addition, specifications as to tree diameter and bark thickness would further facilitate the work.

The value of beneficial agents in control is another important point which will be learned from this study. Already there are indications that beneficials play a part in fluctuations of mountain pine beetle infestations. Exactly how important their role is has not been learned, but when this point has been established it will aid in the prognostication of anticipated increases and decreases in mountain pine beetle infestations in western white pine.

In considering the possibility of fostering native parasites and predators it is essential to know which are the most effective of all the beneficial insects. It is practically impossible to save all of them because the different species attain maximum abundance under diverse circumstances, and it is therefore logical to direct the work so as to assist those species which are most important. It is planned that this study will provide such information in order to preserve the most valuable species, and also to serve as a better basis for determining the status of an infestation.

SUMMARY

The object of this study is to evaluate the biological agencies effective in the control of the mountain pine beetle in western white pine for two purposes, (1) to attempt some modification of mechanical control whereby the benefits derived from natural control factors would not be nullified, and (2) to provide a better basis for prognosticating

anticipated increases or decreases in mountain pine beetle infestations.

Indications are that biological agents play an important role in reducing brood of the mountain pine beetle. The main beneficial insects are Coeloides dendroctoni Cush., Pachyceras eccoptogasteri Ratz., Cecidostiba dendroctoni Ash., Medetera aldrichii Wh., Lonchaea viridana Meig., Enoclerus sphegeus Fab., Enoclerus lecontei Wolc., Thanasimus dubius Fab., Temnochila virescens Fab. var chlorodea Mann., and Phaonia pudoa Hall.

During the 1936-37 season there was a noticeable decrease in abundance of beneficial insects. At the same time there was a decided increase in mountain pine beetle broods.

Beneficial insects are most abundant in those trees which provide suitable host material at the time when oviposition occurs.

Site moisture appears to influence the abundance of beneficials. Parasites, predators, wood-borer work, and woodpecker work are most abundant in trees growing on wet sites, while work by secondary bark beetles is most abundant in trees growing on dry sites.

Accessibility of host material influences the abundance of beneficials. Parasites which oviposit through the bark are limited by bark thickness, while those which go beneath for oviposition are limited by the abundance of entrances such as mountain pine beetle parent-emergence holes.

Parasites are most abundant in small, thin-barked trees, while predators are most numerous in the larger, thick-barked trees.

Beneficial agents are not equally numerous throughout an infestation. Certain areas appear to contain many more beneficials than adjacent areas.

In general, the study appears to hold possibility for practical application along the lines which were set up in the objectives for the study.

Respectfully submitted,

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